Study on the Disaster Analysis and Countermeasures of Subsidence Owing to Steep Seam Mining in Zhaogezhuang Mine

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特　　集

Study on the Disaster Analysis and Countermeasures of Subsidence Owing to Steep Seam Mining in Zhaogezhuang Mine

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Surface collapse pit and bench-shape collapse basin are the main forms of surface movement in steeply-inclined coal-seam mining, and are also one form of mine secondary geological disasters. Based on the mechanical principles and by using limit equilibrium conditions, this article studies the subsiding mechanism, characteristics, the forms of hazard and determinant factors caused by steeply-inclined coal-seam mining through multi-year analysis and summation of the materials concluded by observing the surface movement. Besides, it also analyzes the characteristics of temporal and spatial variation of Zhaogezhuang mining subsidence and offers different management measures according to different types of subsidence so as to achieve the sustainable development of economy and the environment in the mining area.

Keywords : Zhaogezhuang, Mining subsidence, Geological disasters, Management

1　INTRODUCTION

As the land of the mining subsidence does not present itself the moment it is being dug, there is a time difference from the goaf to the subsidence area. This brings about subjective ignoring about the management of goaf，that is, the insufficient estimate of the potential hazard of the goaf. Zhaogezhuang coal mining history has been over a century and the subsidence area has a very bad and serious effect on its peripheral villages，but it has been only several years' time for managing the goaf and doing research into it. How to formulate the integrated control countermeasures and plans for mining subsidence by combining different characteristics of various mining subsidence areas is now an urgent issue which should be deeply studied for the management of our country's collapsed places. Therefore, the management of the mining subsidence is confronted with great difficulties, many problems and there is still a long way to go for it [1-3].

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2　OVERVIEW OF ZHAOGEZHUANG MNING

The coal-bearing stratum of Zhaogezhuang mine is extremely stable and there are seven levels of minable seams. The vertical distribution of the coal seam is the same as the superficial part； the coal seam approximately runs from east to west, tilts to the south and it is divided into two flanks—the east and west during the mining. The gently inclined coal seams and the inclined seams lie in the east part and the steeply-inclined coal seams mainly lie in the west part. In the steeply inclined areas, the inclination angle of the

seam is 45° and it gradually increases along with the development of the coal seam towards the west. The maximum angle of the inclination is above 85°. Owing to the orogenetic movements, an inverted zone in the coal seam has formed near the west boundary.

In mine, surface collapse pit is seen everywhere (Fig.1), the mining subsidence area has been 3860 Chinese acres, the water catchment area is nearly 400 Chinese acres, the maximum water depth is nearly 5m and hundreds of meters of subsidence area has formed in the west mining area. Collective and individual privately-owned small-size coal mines spread over the mining areas from Jinzhuang to Xiaoguzhuang and the boundaries of the well fields in the south of the mining site, which not only destroys eco-geological environment, but also blocks the roads and village planning in the mining site and adversely affects the surrounding residents' normal life.

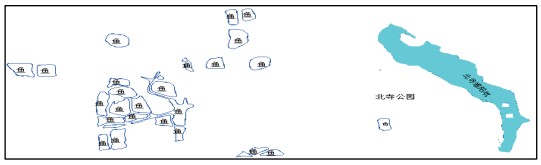


Fig. 1. Subsidence area plan view

3 MECHANSIM AND CHARACTERISTIC OF FORMING SUBSIDENCE

3．1 Collapse Mechanism

The subterranean cavitations have formed during the coal mining and they change the original mechanical balance condition in the rock mass interior. The movement and destruction starting from the nearby stope expand to the surface when the mining area reaches a certain scope. Meanwhile, the subsidence area also increases gradually with the increase of the mining depth and the mining scope. The insiturockmass is at the complicated stress condition, but this is caused mainly by the function of the self-weight stress and the tectonic stress[5]. The rock layer gravity or the tectonic stress makes the change of the rock volume and its shape. The elastic energy gathered by the rock volume compression is:

$$F_T = \left((1-2\mu)\ (1+\mu)^2 \gamma^2 H\right) \Big/ \left(6(1-\mu)^2 E\right)$$

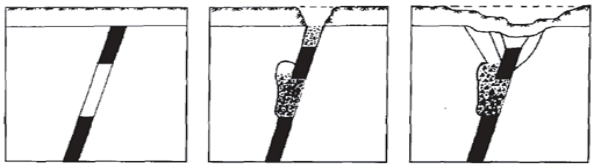
Elastic energy which gathers by rock shape change is:

$$F_x = \left((1-2\mu)^2 \gamma^2 H^2\right) \Big/ \left(6G(1-\mu)^2\right)$$

In the formula: E- elasticity coefficient; G- ehear elasticity; γ- cap rock average bulk specific gravity ; H- cap rock thickness; μ- poison's ratio.

From the above two formulas, if this kind of elastic energy releases under certain conditions, it will then cause movement and deformation of the rock mass.

After the steeply-inclined coal seam has been mined [6], when $F_T=F_x$, the roof rock curves to fall and when the falling rock begins to slide, it forms free space above the goaf (Fig. 2(a)). When $F_T < F_x$, under the function of gravity, ore column separates from the rock mass along the weak rock layer, moves towards the dip-head direction of the coal seam and forms the subsidence funnel on the surface (Fig. 2(b)). If the rock and surface soil which fall into the subsidence funnel are insufficient to support other rock layers, namely, when $F_T \ll F_x$, the subsidence funnel will expand further. When the position which is decided by the rock mass intensity and the rock mass stress in the hanging layer or heading side rock mass forms the tension crack and cutting failure plane, adjacent rock in the hanging layer or heading side will produce asymptotic in break and inclined destruction, and even form the bench-shape subsidence basin on the surface (Fig. 2(c)).



(a) original goaf (b) collapse funnel (c) step-shaped collapse basin

Fig. 2. Asymptotic failure of surface cave in pit

3．2 Collapse Characteristic

Through collecting, analyzing and arranging the material of the mining area, the characteristics of the mining subsidence are summarized below :

1) The method of falling pile up mining coal law (Irregular way of mining) is used by all levels and ultra mining is not forbidden in the mine. Along with this tendency, the amount of the falling coal increases, the vertical height gets longer, the coal seam gradually comes out and falls along the inclined direction. When the height of pulling out braves reaches the height that the rock layer appears (namely under the Quaternary Period alluvium), the surface which is near the place where the coal seam appears presents itself as seriously and no-continuously destroyed, thus it causes the collapse pit which appears on the surface and is inclined to the direction of the coal seam roof .

2) As repeated mining in the kilometer depth attenuates rock characters of the upper rock layers. Although the roof bottom boards of the ninth and tenth level of the mining coal seam both belong to the medium hard rock, the roof bottom board of the ninth level is softer than the tenth level, so rock breaks down very quickly after mining and will form regeneration roof within a certain amount of time. Massive holes form in the temporary structure which is formed between the roof bottom boards. These non-stable structures will cause momentarily possible surface subsidence disasters with the time extension.

3) After the mining site experiencing coal seam

mining for centuries, the surface subsidence、several meters deep subsidence troughs、subsidence pits、open cracks are found everywhere. The underground is very deep and the stability is extremely bad. Engineering geology and ground stability are also extremely bad, and this kind of unstable state continues to extend and expand unceasingly by the way of sudden and intermittent activities. People living in the mining area and the peripheral area suffer a great deal from it.

4) Under the "reverses" special geological structure condition of Zhaogezhuang, the coal synusia with steeply-inclined short distance causes the area that will be affected relatively narrow and small. The place where the coal seam cropouts breaks down braves extremely fiercely and the deep trough type subsidence pit is the main form in this place. The water area is nearly 220 Chinese acres. The maximum water depth is near 5m and the area that is affected by subsidence forms several hundred meters long subsidence belt along the coal seam trend (mainly north temple subsidence belt). Along the coal seam trend in QianJinzhuang Village' southern roadside and outside the west fence flank of Wang Nianzhuang township government, subsidence pit and subsidence belt sink unceasingly with the mining depth's extending and form non-continuous subsidence destruction with its typical forms of open crack and bench-shape around it.

4 INTEGRATED CONTROL COUNTERMEASURE OF MINING SUBSIDENCE

According to analysis of land influence characteristic for Zhaogezhuang mining collapse, the following prevention countermeasure is proposed.

1) Perfect the rock movement observational network in the subsidence area and grasp the subsidence rule so as to provide the scientifically reliable data information for the subsidence management after the mine is deserted. Reasonably arrange the mine entire construction distribution. When arranging the mining of the working area, the strength of mining should be emphasized as much as possible and the mining time intervals between the coal seam should be cut down so as to create conditions for the land reclamation in the mining subsidence.

2) For the stable gentle slope, it can be smoothened as the horizontal broadband terraced field, and for the gentle slope near the water surface, it can be transformed into the paddy field; for the shallow water area whose depth is about 1m, it can be constructed as an intensively cultivated fishing pond by using the method of digging the deep areas and padding the shallow areas or can be reclaimed as a paddy field or as a piece of woods, fruits or vegetables' land; for the water surface with a large water area and a water depth of about 2m, in the region that is near the bank, dams can be built by using gangue or local earth or intensively cultivated fishing pond can be constructed; for the water area with a deep water depth and is far from the bank, fish-farming by way of cage culture or railing fish can be adopted.

3) For the unstable dynamic subsidence areas, the effect of mining subsidence is limited and the ground will not seeper. The farmland can still be cultivated normally after doing some management. It is the best opportunity for the management of the subsidence mining when surface subsidence is quite obvious and the ground seepers the entire year. By grasping this opportunity, the shortcomings of big resilience and construction difficulty while carrying out the management in water can be avoided and the situation that the subsidence land has not been managed and has went out of cultivation for more than 10 mining years can also be avoided. At the same time, the precious pre-peeling plants plow earth can be stored up and used for the field reclamation in the future, or used for transforming the periphery low productivity or inferior quality farmland.

4) To develop tourism industry by using the subsidence reclamation. As to the mining subsidence pits in the mining area, those with deep water, good transportation and agreeable environmental conditions can be chosen. Make a plan of and construct an aquatic park (the north temple park has already been constructed), maintain a suitable water surface. On the one hand, a holiday aquatic park can be provided for the residents living in mining areas; on the other hand, fishery can be developed by using the water surface.

5 CONCLUSIONS

1) On the basis of mechanical principles and by using limit equilibrium conditions, this paper analyzes the subsidence mechanism which is caused by steeply-inclined coal seam mining and enriches and develops the theory of mining subsidence.

2) This paper studies the characteristics of surface movement and deformation and the particularity of mining damage in Zhaogezhuang mine, which will serve as an instruction on the management of the mining damage, ecological environmental protection and the sustainable development.

3) On the basis of summarizing coal collapse area present situation of Zhaogezhuang mining subsidence area, different integrated control countermeasure is proposed for different subsidence area, which will be a practical and feasible, effective government way for mining planning and government.

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概要
地面の崩壊孔と段状崩壊盆地は，急斜面の炭層の採掘における地表変動の大きな主な形式である。そして，それらは採炭地区の二次的な地質災害の一つの形式である。この記事では，力学的な原理に基づき，臨界平衡条件を考慮することによって，沈下の仕組み，特性，危険の形成，決定要因について研究する。この他に，Zhaogezhuang 炭鉱の沈下の空間的時間的な変化の特徴を解析し，そして，持続的な経済発展と採炭地域の環境を両立するような沈下の種類に応じた管理指標を提供する。

Keywords : Zhaogezhuang, Mining subsidence, Geological disasters, Management

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